V/Q Imaging Protocols

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The V/Q scan has traditionally used planar imaging techniques. Image interpretation traditionally adopted the PIOPED criteria to categorise the statistical likelihood of pulmonary embolism. These criteria have long been internationally recognized and understood by both the Nuclear Medicine Physician and referring Practitioners. However, a high incidence of inconclusive results were reported at up to 60% (1) and these criteria are now seen to be completely inadequate in the light of the latest technology (see for example, the discussion of Question #1 in Paul Roach's paper in this brochure). Prior to the introduction of multi-detector CT pulmonary angiography (CTPA) there was virtually no other way to assess if the subject had pulmonary emboli other than planar V/Q scanning, except for an invasive pulmonary angiogram. More recently, SPECT has been used with an increase in sensitivity, specificity and accuracy.

The purpose of this article is to provide insight on the ideal acquisition parameters to use in order to achieve high quality V/Q images. Both a traditional planar protocol and SPECT acquisition parameters have been included, as well as guidelines for reconstruction of SPECT data.

Planar Imaging:

The ideal planar acquisition protocol should take into consideration the numbers of projections required to adequately visualize multiple lobes and segments, the matrix size needed to provide high quality image resolution and the total image counts and the activity administered to the patient. A minimum of 6 views is recommended to allow visualization of multiple lobes and segments, however up to 8 views can be acquired. The traditional views include Anterior, Posterior, Right Anterior Oblique (RAO), Left Anterior Oblique (LAO), Right Posterior Oblique (RPO), Left Posterior Oblique (LPO), Right Lateral and Left Lateral. The following is a set of sample planar acquisition parameters that can be used to obtain high quality images.

Ventilation Planar Acquisition Parameters:

Gamma camera :	LFOV (e.g., 50 x 40 cm rectangular)
Collimator :	Low energy high resolution (LEHR)
Matrix:	256 × 256
Total counts per Image:	300kcts
Number Images:	6 to 8 (Ant, Post, RAO, LAO, RPO, LPO, R+L Lat)
Activity Inhaled:	40MBq (2.0 to 2.5 kcps in the posterior view)
Agent:	[^{99m}Tc]-Technegas

Perfusion Planar Acquisition Parameters:

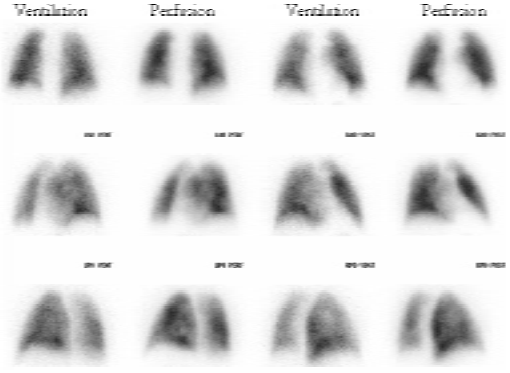
Matrix:	256 × 256
Total counts per Image:	800kcts
Number Images:	6 to 8(Ant, Post, RAO, LAO, RPO, LPO, R+L Lat)
Activity Injected:	130 - 160MBq
Agent:	[^{99m}Tc]-MAA

Total acquisition time for planar imaging depends on whether you use a single or multi-detector gamma camera. For a single detector system, acquisition time is approximately 45 minutes, however on a multi-detector system this time is reduced to about 25 – 30 minutes.

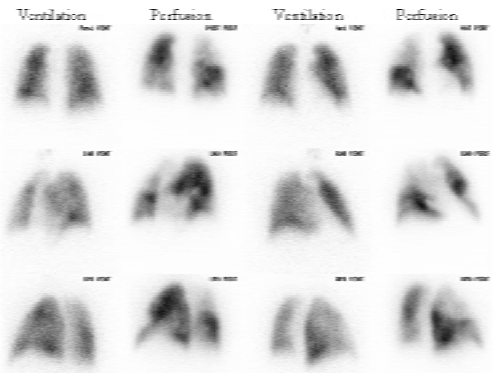
Planar acquisition produces images of high quality that are very reproducible and internationally recognized. An example of a normal ventilation and perfusion lung scan (figure 1A) and a study showing multiple mismatched ventilation and perfusion abnormalities (figure 1B) is shown below.

Figure 1: (A) A normal ventilation and perfusion lung scan showing uniform uptake of both Technegas and [^{99m}Tc]-MAA (macro aggregated albumin) in the lung fields in both studies. (B) Multiple mismatched ventilation and perfusion regions consistent with a diagnosis of multiple pulmonary embolism (PE)

A



B



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Although planar imaging has high sensitivity, with reported values as high as 91% in the PIOPED I study, it lacks specificity in the range of 58% – 87%, with an overall accuracy 85%, with a high rate of intermediate probability studies and an interobserver variability of 33% (2). With rapid advances being made in CT technologies that allow visualization of filling defects up to the sub-segmental level, a need to review the current techniques used for V/Q imaging was highlighted. Planar imaging, by definition involves compressing 3-D structures into a 2-D image and thus could not have the sensitivity and specificity of SPECT imaging. Several recent studies have reported increases in both sensitivity (97%) and specificity (91%) using SPECT imaging when compared to planar (76% and 85% respectively), with an overall accuracy of 94%, making it comparable with CTPA at 93% (3).

SPECT Imaging:

V/Q scanning using SPECT is a 3D imaging technique that allows visualization of segments previously not identified on planar imaging, such as the medial basal segment of the right lower lobe, with more clearly defined lung segments and an improvement in the detection and characterisation of defects. SPECT improves image contrast and decreases the rate of intermediate scan reports with moderate defects now shown with improved contrast (4).

Determination of the ideal SPECT acquisition parameters should take into account the following:

1. Number of projections (N^P) (or stops) – the number of projections needed to obtain a good quality study can be determined using the following formula and is dependent on the FOV (field of view) size occupied by the organ of interest (D) and the reconstructed spatial resolution (FWHM) of the system, both in mm:

$$N_p = \frac{\pi D}{(FWHM/2)}$$

Typical values in lung SPECT could be D=350mm and FWHM = 18mm, suggesting $N^P \approx 120$ projections;

2. Time per projection - can be adjusted based on the activity administered to the patient and the count rate (cps) obtained at the time of scan. Total acquired events per projection should be in the range of 35-45kcts for ventilation and 130-150kcts for perfusion;

3. Matrix size – SPECT acquisition should always use a minimum of 128 × 128 matrix size in order to achieve high image resolution;

4. Acquisition Zoom – will vary dependent on the FOV size. Large dual-detector systems with ~40cm FOV may need a zoom factor, up to 1.5 – 1.8;

5. Administered activity to patient – an increase in administered activity of both the ventilation and perfusion agents should be considered in order to maximise image quality without significantly increasing total acquisition time compared with planar imaging. At our institution we use an inhaled dose of 50MBq (2.5–3.0 kcps) for Technegas and 220MBq of [^{99m}Tc]-MAA, but satisfactory results have been reported with lower administered doses. This should be in keeping with your local regulations on radiation protection.

Ventilation SPECT acquisition parameters:

Collimator	LEHR
Matrix	128 × 128
Acquisition Orbit	360^0
Np	120 images
Radial sampling	3 degree steps
Zoom	1 to 1.8 (Dependent on detector FOV size)
Orbit Type	Non-Circular Continuous or Step and Shoot
Time per Projection	15-20 seconds
Isotope	[^{99m}Tc]-Technegas
Peaks	140keV
Energy Window	20%
Administered Dose	40–50MBq
Total Time	10 -15 minutes

Perfusion SPECT acquisition parameters:

Collimator	LEHR
Matrix	128 × 128
Acquisition Orbit	360^0
Np	120 images
Radial sampling	3 degree steps
Zoom	1 to 1.8 (Dependent on detector FOV size)
Orbit Type	Non-Circular Continuous or Step and Shoot

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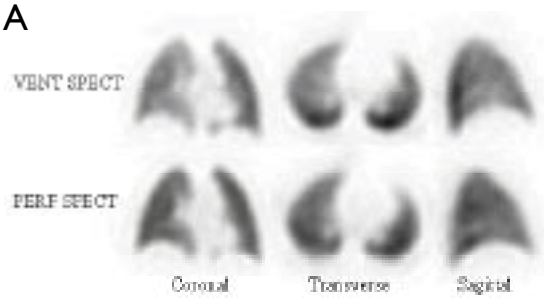
Time per Projection	12-15 seconds
Isotope	[^{99m}Tc]-MAA
Peaks	140keV
Energy Window	20%
Administered Dose	160–220MBq
Total Time	8 – 12 minutes

SPECT acquisition allows visualization of all segments and lobes, with reviewing of image data in the 3 orthogonal planes – transverse, coronal and sagittal. This improves image contrast resolution and quality. Examples of a normal ventilation and perfusion lung scan (figure 2A) and a study showing multiple mismatched ventilation and perfusion abnormalities (figure 2B) are shown below.

A



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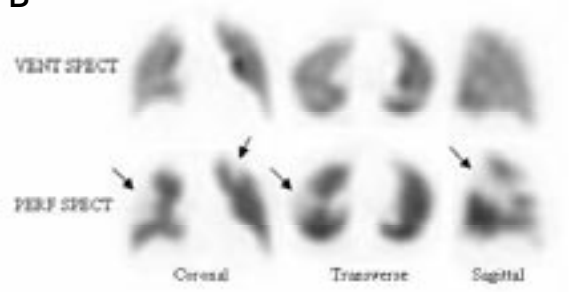

Figure 2: (A) A normal ventilation and perfusion lung scan showing uniform uptake of both Technegas and [^{99m}Tc]-MAA (macro aggregated albumin) in the lung fields in both studies. (B) Multiple mismatched ventilation and perfusion defects confirming a diagnosis of multiple pulmonary embolism (PE)

SPECT Reconstruction:

It is recommended OSEM (Ordered Subset Expectation Maximization) be used for SPECT reconstruction, with the number of subset and iterations used in the reconstruction based on the number of acquired projections, the pixel size of the images and the matrix size. Generally 4-8 subsets and 2-4 iterations will produce good images within a reasonable processing time. This can vary between camera systems and software packages. Filtering will be set based on the total counts per image. As a guide, a Butterworth or low-pass filter using a cut-off (Nyquist frequency) of 0.7 to 1.0 and an order of 6 to 10 will produce good quality images.

Many software packages are available for registration of data. Ventilation and perfusion reconstructed transverse studies should be co-registered before interpretation. A mutual information algorithm with at least 6 degrees-of-freedom is recommended. Scaling and warping should not be needed when registering as image size should be identical. It is essential to review image data synchronized and triangulated in the three planes as a quality control check of the data.

Planar Generation Using SPECT Data:

There are many benefits of performing V/Q SPECT including improvements in sensitivity, specificity and accuracy; however image interpretation becomes more complex. Having the ability to generate planar images from SPECT data may be important especially in the initial implementation phase when SPECT is first introduced. There have been a number of methods reported in the literature for generation of planar images from SPECT data. The "angular summed" method of Reinartz (5) adds acquired images over a particular range to generate multiple planar projections using the SPECT acquisition data. These are quick and easy to generate but have some blurring due to summing over a finite angular range (10°-15°) (5). They are also prone to be count poor. An alternative method, which we developed, is based on re-projection of the attenuation (μ) corrected (AC) reconstructed SPECT images using the entire SPECT dataset by use of either a CT-based μ-map or a synthetic attenuation μ-map (6). In order to create a synthetic μ-map, an additional energy window is acquired simultaneously with the emission window during SPECT acquisition. A scatter energy of 108keV with a 25% window is ideal. This μ-map is used to generate an AC transverse reconstructed SPECT dataset. These volume data are then forward projected to generate planar images in multiple projections, including "single-lung" medial

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and lateral images by removing interference from the contra-lateral lung. Comparison of acquired planar images with both methods of planar image generation using SPECT data show good correlation, although angular summed planar images may not detect some smaller perfusion defects in approximately 10% of cases due to image blurring. The re-projection method has sharper edge definition and higher contrast (figure 3). Re-projected planar images have contributions from the entire SPECT dataset, typically 8-12×10^6 cts per planar image.

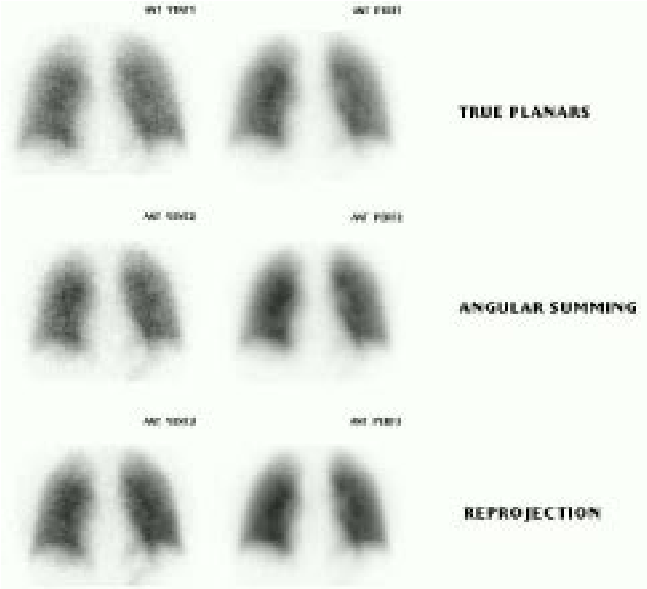

Figure 3: Example of a normal study in the anterior and posterior projection. (A) Acquired planars using total image counts of 300kcts for ventilation and 800kcts for perfusion. (B) Angular summed method of SPECT planar generation highlighting blurred edges due to summing over a finite number of angles. (C) Re-projection method of SPECT planar generation using the entire study to forward project planar images in multiple projections that have sharper edge definition and higher contrast.

Advantages of SPECT

SPECT offers the advantage of being able to visualize all segments of the lungs in the 3 orthogonal planes, and detecting mismatches that cannot be seen on traditional planar images. This is demonstrated in the example seen in Figure 4, where no mismatched defects are readily seen on either the angular summed planar or the re-projection planar images. However on SPECT imaging, multiple small mismatched ventilation and perfusion defects can be clearly identified.

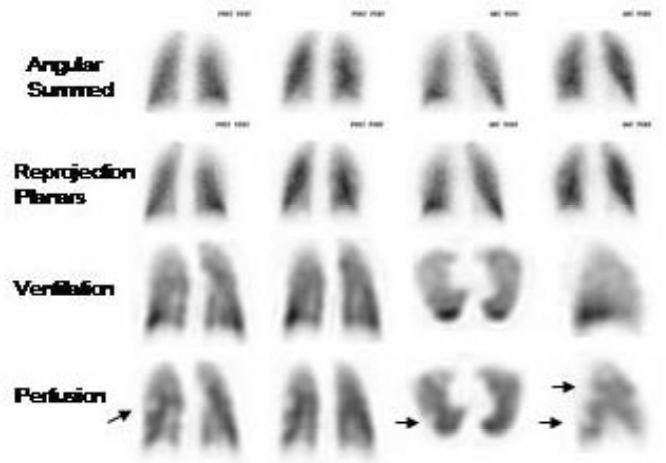

Figure 4: An example of multiple mismatched ventilation and perfusion defects identified on SPECT imaging only. (A) Angular summed planar images and (B) re-projection planar images demonstrating no mismatched defects. (C) SPECT imaging in the coronal, transverse and sagittal planes identifying multiple small mismatched ventilation and perfusion defects not identified on planar imaging.

Being a true 3D acquisition process, SPECT allows for the inclusion of other imaging techniques and methods of analysis that can improve the accuracy of image interpretation. Advances in technology have made SPECT/CT more readily available through the use of either a dedicated SPECT/CT system or software fusion packages. The use of either low-dose CT (LDCT) or CTPA with V/Q SPECT for investigation of pulmonary embolism (PE) has been shown to improve diagnostic accuracy for this condition (7). It can also suggest other causes of V/Q SPECT abnormalities not typical of PE, as seen in figure 5. This study confirms that the perfusion abnormalities correlate with a RML lung cancer.

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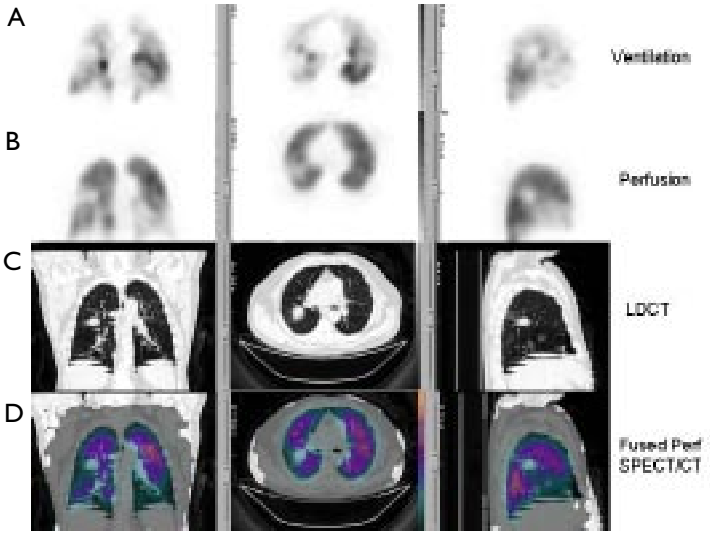

Figure 5: V/Q SPECT/CT scan confirms a RML lung cancer as the cause of the perfusion defect. (A) Ventilation SPECT and (B) Perfusion SPECT demonstrating a matched defect in the RML, (C) with a corresponding RML lung tumour identified on LDCT. (D) Fused SPECT/CT images confirm these findings.

New methods of interpreting image data, such as objective analysis by examining pixel-based V/Q ratios, have been shown to have a high diagnostic accuracy in PE, with the potential to decrease the number of non-diagnostic or indeterminate scans (8, 9). A V/Q ratio image identifies areas of mismatch in ventilation and perfusion using a predetermined threshold and subtracting ventilation activity from perfusion images to show true perfusion data only. As can be seen in figure 6, V/Q mismatches can be easily identified and should help the clinician to confirm the findings identified V/Q SPECT imaging.

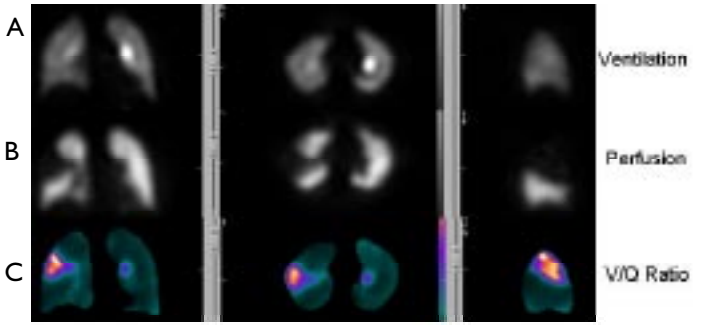

Figure 6: (A) Ventilation SPECT showing uniform distribution of Technegas throughout lung fields. (B) Multiple areas of perfusion reduction identified. (C) V/Q Ratio images confirming areas of mismatch identified on V/Q SPECT.

V/Q SPECT imaging has many advantages over traditional planar imaging and has been shown to improve the sensitivity, specificity and overall diagnostic accuracy of the lung scan, and with a significantly lower radiation dose compared with CTPA.

References

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